The Apollo Program: Science/Engineering Personnel Demand Created by a Federal Research Mission

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Sources for Estimates of S&E Demand

The Apollo program is the paradigm of a Federal research and development program directed to the fulfillment of a high-priority national mission. Conceived, developed and carried to a successful conclusion by the National Aeronautics & Space Administration (NASA), Apollo's goal was to land a man on the Moon and return him safely before the end of the 1960s.

But before a lunar landing could be accomplished, many other things had first to happen. Within five years of its establishment, NASA had grown from a small research organization into one of the largest civilian agencies; new facilities had to be built, such as the Kennedy Space Center at Cape Canaveral, Florida, and the Manned Spacecraft Center at Houston, Texas; and most important, NASA had somehow to find and recruit the scientists and engineers (S&E) without whom a major engineering effort like Apollo was scarcely attainable. The subject of this paper is how a Federal research priority, Apollo, created a sudden shortage of technical personnel, and how the demand for these personnel was met.

Specifically, this paper will examine several related areas: Were the manpower resources for Apollo available when they were needed? Did Apollo succeed in creating research capabilities that outlasted the program that created them? Finally, can we manage Federal research missions better, based on the Apollo experience? Before turning to these questions, it is necessary

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to look at two other issues. These are the data sources for an examination of Apollo S&E needs, and the ways by which NASA determined its manpower needs.

There are three main data sources for the 1960-1970 period on which this paper focuses. First, there are the data that NASA kept on its operations; some of these are available only as unpublished memoranda, others as responses to congressional inquiries, while still others appear in published reports. Second, there are the recurring and occasional reports, notably those of the National Science Foundation and the annual Manpower Report of the President prepared by the Department of Labor. Lastly, there are several task force reports prepared by, among others, the National Research Council and the old President's Science Advisory Committee. This report is indebted to all of them.

Yet these sources, even the most authoritative of them, are no better than the data available to the persons who compiled them. Thus a Labor Department report may extract data from a National Science Foundation publication that, in turn, depends on the adequacy of the survey data it received from the agencies. In some cases, the data in a report may be two or three levels removed from the actual sources.

But the difficulties in using the data go deeper. One of them has to do with defining terms. Where NSF, for example, classifies persons working in different sectors of R&D, one encounters the notorious difficulty of defining terms like "basic research," "applied research," and "development" with precision. Further, in those NSF reports that cover S&E doctorates, the categories themselves change. In its Science and Engineering Doctorates: 1960-81 (NSF 83-309), the first of a series, NSF combined one category, Astronomy and Astrophysics, for the 1960-1968 period, and broke them out separately thereafter, without indicating if the two separate categories were

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identical to the original combined one.

Another difficulty pertains to the fact that the great majority of S&Es working on Apollo were not directly employed by Apollo. The majority worked for NASA prime contractors, but others worked for first- and second-tier subcontractors, for universities and contract research centers, or as principal investigators on Apollo flight experiments. (The NSF figures also understate the number of S&E personnel working in Federal intramural research, since workers at government-owned, contractor-operated facilities, like NASA's Jet Propulsion Laboratory or the weapons labs of the Atomic Energy Commission did not count as Federal employees). To further complicate matters, some of those listed as scientists and engineers were employed in positions that did not require such training.

In sum, the problems with these data relate to definitions, to the lack of consistency within and between time series and to the paucity of data for areas within the scope of this study. There is little hard data available on what became of graduate students trained in Apollo-related disciplines like astronomy, after NASA cutbacks reduced job opportunities for graduates. Similarly, the second- and third-order consequences of university programs funded by NASA grants are difficult to quantify, altough (as will be seen) efforts have been made by NASA and independent scholars.

There is one other limitation in these figures so obvious that it is easily overlooked. The reports of NSF, the Labor Department and NASA are after the fact; they are primarily historical data, not forecasting tools. Yet the question of how NASA estimated its manpower needs for Apollo is extremely important and needs to be explored. Under normal conditions, an agency projects its staffing needs in terms of its current budget, with minor adjustments for ensuing fiscal years. But NASA, from mid-1961 to the end of

1963, was in the position – rare for a Federal agency – of having a virtual blank check to recruit scientific and technical manpower. How the agency's senior officials arrived at an estimate is discussed below.

The Nature of the Apollo Mission

Established by Congress in 1958 in the aftermath of Sputnik, NASA grew out of the National Advisory Committee for Aeronautics (NACA). With 8000 employees in 1958, NACA was a small, highly-respected agency that had done important research in aeronautical science in its own laboratories. NACA was a logical choice to be the core of the new agency. It had a specifically technical orientation, a highly trained technical staff, a recent history of research on flight in the lower reaches of space, and excellent working relations with the Department of Defense.

Yet the new agency was to be something more than a reconstituted NACA. The Space Act that created NASA replaced an advisory committee with a strong administrator, authorized NASA to contract out for hardware, support services and university-sponsored research, and empowered it to conceive and carry out major development programs, including the development of large launch vehicles. NASA was further strengthened when, over the next two years, it took on facilities and programs that were transferred from Defense programs: the F-1 rocket engine, the Jet Propulsion Laboratory, the team at the Naval Research Laboratory that planned the Vanguard project, and the rocket team under Wernher von Braun that became the nucleus of the Marshall Space Flight Center in Huntsville, Alabama.

From the moment of its creation, NASA officials began to consider the potential of manned space programs. The first such program, Mercury, would

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test the ability of one man to function up to several hours in Earth orbit. But a number of younger engineers working for the Space Task Group, which managed Mercury, were interested in more ambitious programs. By 1960 a headquarters group had recommended that NASA plan a lunar landing for some time after 1970, a prediction soon to be overtaken by events. In July 1960 NASA announced a manned circumlunar mission project to be called Apollo.

Yet at the beginning of 1961 the future of NASA's manned programs was uncertain. The previous December a PSAC study reported that a manned lunar landing was feasible, but that it would cost between $26 and $38 billion; and in January an Ad Hoc Committee on Space advised President-elect John F. Kennedy of grave deficiencies in the national space program: "inadequate planning and direction. . . the lack of outstanding scientists and engineers." The report further criticized NASA for emphasizing its manned programs at the expense of the more scientifically productive unmanned probes.

Why, then, did President Kennedy commit the nation to a lunar landing as and when he did? The decision was shaped by many considerations: NASA's assurance that it was possible and could be accomplished for under $7 billion; the crucial role of Vice President Lyndon Johnson as chairman of the Space Council, an umbrella committee created by the Space Act; the humiliating news of Yuri Gagarin's Earth-orbital flight of April 12 and the failure of the Bay of Pigs invasion a week later; and the conviction — strengthened by NASA Administrator James Webb and Defense Secretary Robert McNamara — that a manned lunar landing was the logical, inevitable way for the United States to demonstrate its superiority in space.

On May 25, 1961, President Kennedy came before Congress to request funding for a greatly-expanded Apollo. Specifically, he proposed a lunar landing within the decade — the language suggested by Webb. But this program

would spin off additional development projects in scientific work, worldwide satellite communications and weather prediction systems and the concurrent development of liquid-fuel boosters by NASA and solid-fuel boosters by the Air Force.

The decision to go to the Moon reordered all of NASA's program with reference to one central, all-important goal. Ranger and Surveyor, originally conceived as open-ended and predominantly scientific programs, were now to do the preliminary scouting of the lunar surface for Apollo. An even more important shift pertained to the role of NASA prime contractors. Instead of the centers doing most of the work in-house and using industry for support services, the roles were to be reversed, with industry handling production and most of the design, while the centers approved or disapproved of changes and checked performance against schedules and cost. It was obvious to Webb that industry and the universities had to be brought in, not only for the urgently practical reason that this was the only way to get the job done, but because it was a way of building support — by geographical area, by political affiliation, by economic interest.

One of the most important aspects of the Apollo program was the speed with which the crucial administrative and program decisions were made and the major prime contracts awarded. Except for the decision to test all the major Apollo components together, the principal Apollo program decisions were made between August 1961 and the end of July 1962. During these 12 months, NASA selected the contractors to expand its launch facilities and build new ones, announced the selection of Houston as the site of the new Manned Spacecraft Center, and announced a new program, Gemini, to fill the gap between Mercury and Apollo. Gemini would involve a two-man crew using a more advanced version of the Mercury capsule, and its main purpose would be to develop the

capability for a spacecraft to rendezvous with a target in Earth orbit.

The period from early 1962 to the end of 1966 marked Apollo's early development phase. As NASA negotiated the major prime contracts and as actual development work began, agency executives began to fine tune the program. The first half of this period saw the most intensive hiring campaigns, with total employment (contractor and civil-service) rising from 139,000 in mid-1962 to 420,000 in early 1966. Most of the early flight projects in support of the lunar landing began to pay off; thus after six consecutive failures, the last three Ranger flights in 1964-1965 returned thousands of accurate photos of the lunar surface, with resolution to 30 centimeters.

At the same time, top management delegated to the program offices and centers the authority to get the job done. A November 1963 reorganization placed the centers under the program offices, instead of reporting directly to the Associate Administrator. Additionally, NASA decided not to build up capabilities where the private sector could fill the need. The one partial exception was the decision to create an Electronics Research Center in the Boston area. This proposal was broached by NASA in the fall of 1962, introduced into the budget the following January, authorized by Congress in July 1964, and formally implemented when NASA accepted the offer of a site in Cambridge that August. With this exception, the NASA organization – a combination of decentralized project execution with centralized planning and control – changed comparatively little during the next seven years.

This record of success was brutally cut short by the January 1967 fire that killed three astronauts in an Apollo command module brought to the Cape for preflight testing. Subsequent investigations by Congress revealed that NASA had known for two years prior to the accident that North American Aviation, the prime contractor for the Apollo spacecraft, was not meeting its

design, schedule and cost specifications. In the end, Apollo slipped 18 months. At a cost of an extra $41C million, and a reorganization of North American's space division, NASA redesigned the spacecraft, brought in Boeing to integrate it with the Saturn 5 booster stack, and created an Office of Organization and Management to tighten headquarters control over the centers.

There were to be few failures thereafter. From the first unmanned launch of the Saturn 5 to the first flight of the three-man crew in October 1968 to the lunar landing on July 20, 1969, Apollo went from strength to strength. By then, however, Apollo was a program in decline. NASA had begun cutting its workforce as early as mid-1966; and by the fall of 1967 it was going down at the rate of 4000 a month. With congressional cutbacks — owing to Vietnam and the pressure of domestic social programs — NASA officials consciously decided to sacrifice other programs to the success of Apollo: cutting back research at the older, NACA-based centers; eliminating certain scientific programs before they reached the development stage; closing the Electronics Research Center at the end of 1969, even as work on the facility continued; and finally, under pressure from the Office of Management and Budget, canceling the last two Apollo flights in 1970. The final mission, Apollo 17, did not fly until December 1972. By then, however, NASA was committed to a radically different program, involving a reusable Space Shuttle that could place spacecraft in orbit and retrieve them, and serve as a support for the orbiting space station that NASA hoped to build.

Yet Apollo must be judged one of the great successes in managing large-scale endeavors. One reason for the success, which the rest of this paper explores, was NASA's skill in recruiting the professional employees it needed to design and run Apollo. But this success depended, in turn, on key administrative decisions that ultimately affected NASA's need for S&Es.

Underlying all of NASA's programs was the decision – taken from the beginning – to rely on American industry and universities to "spread the difficult problems over the largest number of able minds" (Webb). This was the key internal decision in NASA's history. NASA could have been an "arsenal" agency, doing all the work itself, or it could have contracted out virtually all of its R&D, as the Atomic Energy Commission did. NASA did neither; the first approach would have been inadequate for Apollo, while the other would have left NASA more or less at the mercy of its contractors. As Webb recognized, for this approach to be effective, "NASA had to have very strong scientific, technical, and administrative in-house capabilities."[1]

What roles did NASA assign its in-house professional employees? The rationale for an in-house technical staff was to enable NASA to retain those functions that no government agency has the right to contract out, functions enumerated by a former Director of the Budget as "the decisions on what work is to be done, what objectives are to be set for the work, what time period and what costs are to be associated with the work, what the results expected are to be. . . the evaluation and the responsibilities for knowing whether the work has gone as it was supposed to go, and if it has not, what went wrong, and how it can be corrected on subsequent occasions."[2]

This, in fact, was NASA's position: that the rapid buildup of the Gemini and Apollo programs precluded reliance on government employees alone; that it was agency policy not to develop in-house capabilities already available in the private sector; that NASA employees were needed for technical direction

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1. James E. Webb, Space Age Management: The Large-scale Approach, McKinsey Foundation Lecture Series, Graduate School of Business, Columbia University (New York: McGraw-Hill, 1969), p. 113.
2. Testimony of David E. Bell, Director, Bureau of the Budget, U.S. House of Representative, Committee on Government Operations, Subcommittee on Military OPerations, Systems Development and Management, 87th Congress, 2nd Session (June 21, 1962), p.44.

rather than for hardware fabrication or routine chores; and that it was better to let the up-and-down swings in manpower take place in the contractor, rather than the civil service, work force. NASA was prepared to go even further. When budget cutbacks began in 1967, NASA laid off its own employees at several centers before dismissing contract workers, and its position was sustained in the Federal courts.

Another feature of the NASA organization was the combining of responsibility for programs and hardware in the same program office. The heads of each major program office – Manned Space Flight, which ran Apollo, Space Science and Applications, and Advanced Research and Technology – were to be corporate vice presidents. Or as Webb said, each program office head "was a guy running his show as an Associate Administrator [who] ought to think of himself as nearly as possible doing the total job. He had to present his program to Congress – he wasn't just an internal manager."[3]

This view meant that the centers were responsible for project management. For all flight projects except Apollo, there was to be one lead center, regardless of how many centers actually participated. In the case of Apollo, the major elements were given to lead centers: the spacecraft to Houston, the launch vehicle to Marshall, the tracking system to the Goddard Space Flight Center in Greenbelt, Maryland. The tools for getting the job done had to be grouped in related fashion. Thus a particular center had to have the capacity to manage large development contracts, the skills to integrate the subsystems of a project parceled out among two or three other centers, and the ability to draw on the resources of other centers instead of needlessly duplicating them.

3. Arnold S. Levine, Managing NASA in the Apollo Era (Washington, DC: NASA Scientific & Technical Information Branch, 1982), p. 43.

This was the way NASA was organized for Apollo, and the system worked just long enough to accomplish its ends. The important decisions were made at the right time; agency officials had a flexibility in negotiating contracts and hiring personnel that no other agency could match; and the top managers understood the political implications of NASA missions. The following sections explore the tools available to NASA in meeting its manpower needs, the kinds of skills on which the agency drew, and the repercussions of its recruiting policies – whether for direct hires, contract managers, or university researchers.

Characteristics of NASA S&E Workforce

The 1960s began with a tremendous increase in NASA manpower, followed by a contraction as marked as the expansion that preceded it. The number of contractor employees alone doubled in 1961-1962 and again in the following year[4] to the point where 420,000 persons were working directly or indirectly for NASA at the beginning of 1966.[5] This marked the turning point; from a total of 396,000 employees at the end of June 1966, agency employment fell to 307,000 in 1967, to 268,000 in 1968, and to 218,000 in 1969.[6]

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4. From 57,500 at the end of June 1961 to 115,500 one year later and to 218,000 one year after that. NASA Data Book, Vol. I: NASA Resources (Washington, DC: NASA Scientific & Technical Information Office, 1976), table 3-26.

5. This is the figure given by NASA Deputy Administrator Robert Seamans for the third quarter (January-March) of fiscal 1966. U.S. Congress, House of Representatives, Committee on Science and Astronautics Committee, 1968 NASA Authorization, 90th Congress, 1st Session (1967), p. 111.

6. NASA Personnel Division, Personnel Division Report: The In-House Work Force, Sept. 1969, p. 3. All figures are as of June 30. The employment figures are divided between contractor and in-house employees as follows: 1966, 360,000 contractor and 36,000 in-house; 1967, 273,000 and 34,000; 1968, 235,000 and 33,000; 1969, 186,000 and 32,000. The 11-percent decline in the NASA workforce from 1966 to 1969 conceals variations between one center and another in personnel reductions.

NASA had a high proportion of S&Es – higher, perhaps, than in any other agency doing R&D. Between 1960 and 1968 their share of the total NASA workforce was fairly constant, ranging between one-third in 1961 and two-fifths in 1967. If the figures for in-house and contractor S&Es are combined, the total was a constant one-fourth throughout the period (Table 1).

TABLE 1

NASA SCIENTISTS AND ENGINEERS AS A PERCENTAGE

OF NASA EMPLOYMENT, 1960-1968

(June 30 Approximations)

But these figures must be examined before their significance becomes apparent. The lack of widely accepted definitions may be one reason why statistical breakdowns that would compare NASA employment of S&Es with other R&D agencies are so hard to come by. The matter is further complicated because NASA grouped S&Es under three separate occupational codes. NASA defined scientists and engineers as "all persons primarily engaged in the performance or direction of scientific, engineering, mathematical, or other technical professional work requiring a 4-year college major. . . in engineering or in physical, life, or mathematical science."[7] This would exclude persons trained in the social sciences, including statisticians, and leave open the occupational group to which computer programmers belong.

Of the total, all but an insignificant number of S&Es were grouped under occupational code 700 (scientific and engineering positions), a classification that included persons with aerospace technology qualifications. This qualification was important chiefly because of the special examination that the Civil Service Commission authorized NASA to employ, beginning in 1962. This examination was for NASA's use alone; and NASA officials hailed Part C, "for work in Research and Development Administration," as an "advance in selective examination and recruitment."

What made the examination, especially Part C, unique, was that the applicant had to demonstrate "understanding of research and development organizations and their specialized problems, organizational structures, functions, operations, and characteristics."[8] The beauty of this requirement

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7. This definition is included as part of NASA's reply to a series of questions submitted by Senator Gaylord Nelson (D-Wis.), chairman of the Subcommittee on Employment and Manpower, Committee on Labor and Public Welfare. NASA assembled a number of papers and tables and titled the collection Reply to Sen. Gaylord Nelson (1965). This definition is taken from the Reply, p. 12-1.

8. Robert Rosholt, An Administrative History of NASA, 1958-1963 (Washington,

was its openendedness: NASA could add specialties, give the examiner discretion in interpreting requirements, and generally make use of a hiring freedom unmatched by any other agency. NASA personnel controlled the examination at the critical points: they administered it, they rated it, and they gave it much of its specific content. The aerospace technology examination "provided a means for NASA to fill almost all of what could be termed its 'professional' positions. This, combined with the power of the Administrator to make 'excepted' appointments, gave NASA almost complete control over whom it hired."[9]

Table 2 shows that the major hiring campaigns occurred in 1962-1962 and 1962-1963. Approximately 70 percent of newly hired S&Es came from either industry or government. In 1963-1964 the source of new technical hires shifted significantly from government to industry, while recruitment from colleges and universities stayed constant at 23 percent. All this was in marked contrast to contractor experience. Most of their new hires came from other industrial organizations or other plants and divisions of the same company, with an insignificant percentage recruited from government.

DC: NASA Scientific & Technical Information Office, 1966), p. 267.
9. Ibid., pp. 267-268.

TABLE 2

ORGANIZATIONAL SOURCES OF NASA IN-HOUSE SCIENTISTS AND ENGINEERS

Table 3, which gives the figures as of mid-1964, reveals that 85 percent of the S&Es in the NASA workforce were employed by private industry, including the Jet Propulsion Laboratory; 83 percent were working on NASA programs funded by the research and development appropriation; 62 percent were employed under the direct supervision of the Office of Manned Space Flight; and of these, 10.8 percent (5450) were NASA employees. These figures also show that while 38.2 percent of total NASA civil service employees were S&Es, only 19.8 percent of contractor employees were.[10] At the same time, each NASA scientist or engineer had more contractor employees to supervise: where there was 1 NASA scientist or engineer for 1.5 contractors S&Es in 1960, there was only 1 for every 5 in 1964, and 1 for every 5.5 in 1966.[11] The last figure is an estimate from budget projections for fiscal 1966.

10. Reply to Senator Gaylord Nelson, p. 12-3.
11. Ibid., p. 12-6.

TABLE 3

TOTAL SCIENTISTS AND ENGINEERS ON NASA WORK BY PROGRAM OFFICE,

JUNE 30, 1964

These figures are not really comparable to those of other agencies, because no other agency – save for certain weapons programs sponsored by the military services – was so driven by the need to complete a very ambitious mission within a certain time. NASA, with its project-oriented supervision of contractor employees, had almost nothing in common with the way in which (say) the National Institutes of Health supervised its grantees or the Atomic Energy Commission oversaw its contractor-operated laboratories. Yet the figures do appear to undercut the rationale for a large in-house professional work force: that only such an organization could be an "educated buyer" of the services that the private sector offered.

As the ratio of NASA S&Es to contractors dropped in the late 1960s, many of the center directors complained that NASA came to depend on industry for what should have been done in house. As the Director of the Manned Spacecraft Center wrote a few months before the Apollo 11 landing in July 1969:

> We have agreed with the 'surge tank' philosophy and have recognized that an adequate in-house manning of Civil Service personnel was out of the question. However, we think that this in-house capability should have been greater and have, from time to time, requested a larger in-house manning. . . We have been very weak in systems engineering, analysis, and trajectory work. We have developed practically no engineering competence in the field of Reliability and Quality Assurance. We have probably been too dependent on Philco, IBM and TRW in the operation of the Mission Control Center and in operations generally.[12]

How did NASA S&E requirements compare with national requirements in the same categories? Table 4 shows that NASA manpower requirements were 4.6 percent of national requirements in 1964, rising to 5.4 percent in 1965.

12. Memo, MSC Director Robert Gilruth to Associate Administrator for Manned Space Flight George Mueller, January 9, 1969, in Arnold S. Levine, Managing NASA in the Apollo Era (Washington, DC: NASA Scientific & Technical Information Branch, 1982), p. 92.

TABLE 4

NASA REQUIREMENTS FOR SCIENTISTS AND ENGINEERS COMPARED

WITH NATIONAL REQUIREMENTS, 1960-1970

Was NASA, in projecting this demand, only asking its fair share of scientific and technical manpower? There is very little to indicate that NASA officials projected their needs in any such systematic way. What limited evidence there is points in the other direction. According to Homer Newell, who directed NASA space sciences programs from 1961 to 1967, NASA was faced in the early 1960s with starting a program to support graduate study in space-related areas. While NASA was grappling with this issue, the President's Science Advisory Committee had assembled a panel to consider the nation's need for persons trained in engineering, mathematics and the physical sciences. Although this panel, chaired by MIT engineering professor Edwin Gilliland, did not issue its report until December 1962, NASA knew the report's conclusions months before they appeared.

The Gilliland Report concluded that by 1970 the country would have to double its production of engineers, mathematicians and physicists. According to Newell, "this equated to adding about 4000 persons at the doctorate level to the work force each year. Comparing its total budget with those of sister agencies like the Department of Defense, the National Science Foundation, and the National Institutes of Health, NASA arbitrarily adopted one-fourth of the goal as its fair share. Finding itself unable to meet this goal, the [NASA] university office ultimately aimed at a steady-state level of 1000 trainees in its program."[13]

Acting on the limited information available to them, NASA officials used three methods to recruit the manpower the agency needed. The first, as just indicated, was to employ the few available projections to determine its fair share of the national manpower pool. Once having determined this figure, NASA

13. Homer E. Newell, Beyond the Atmosphere: Early Years of Space Science (Washington, DC: NASA Scientific & Technical Information Branch, 1980), p. 227. Emphasis added.

used the instruments made available by Congress and the Civil Service Commission to recruit directly to the agency. In particular, NASA officials did their utmost to raise the ceiling of so-called "excepted" and "supergrade" positions that Congress allotted. These were the positions filled by higher-level executives, as well as the project engineers and scientists who managed NASA operations.

Webb and his associates worked hard to extend their authority to fill excepted positions by persuading Congress to raise the level of such positions, reserving as far as possible a certain number of excepted positions for "quick hires" of executives from outside the agency, and doing what they could to keep the center directors and program managers at the highest levels authorized by the congressional salary acts. The most important technical result of these authorities was to give NASA the qualified professionals it had to have to accomplish the Apollo mission. The most important administrative result was to give the agency head the leverage he needed to structure NASA. Both Webb and his predecessor, T. Keith Glennan, thought of these positions as a resource personal to themselves, a resource that they could use to structure the agency at the higher levels without the need to seek congressional approval.

The second approach NASA used was to state its program requirements and leave it to contractors to satisfy them. In this way, the responsibility fell on the contracting firm to demonstrate that it had the manpower to carry out an assignment, such as building the lower stage of the Saturn rocket, supplying circuitry for the instrument panel of the Apollo spacecraft or building one of the pads from which Apollo missions were to be launched. With rare exceptions like the Jet Propulsion Laboratory, NASA chose to work through existing organizations rather than setting up captive organizations on the

order of the RAND Corporation, with NASA as their prime sponsor.

The third approach was to create a critical mass of scientific and engineering talent that would be available to NASA. But it is important to note that in the mid-1960s NASA was supporting a great deal of research that was not specific to any mission; that it became NASA policy to strengthen universities while at the same time getting NASA's job done; and that NASA grants were often controlled locally rather than at agency headquarters.

NASA, then, succeeded in managing the very rapid buildup of scientific and technical manpower needed to drive Apollo. But it was less successful in promoting a gradual reduction in its work force, as its appropriations fell from mid-1967 on. Part of NASA's problem stemmed from the difficulty that agency executives had in deciding how to regard manpower requirements. As a 1966 staff paper noted, NASA could take one of three general positions regarding future trends in manpower. The first was that manpower requirements would be determined entirely by the needs of each program. Viewed in this light, this position would have meant that NASA was "a master job shop and that individuals are hired to perform specific approved projects and are separated when those projects are terminated."

The second approach would have been that NASA hired on a career basis and that, within broad limits, personnel should be retained with little regard to the particulars of any single program. The third, intermediate position that NASA finally adopted was that some personnel were a permanent asset to the agency and that the employment of the others would depend on the life of specific projects.[14] Table 5 shows the first wave of reductions in NASA

14. Draft discussion paper prepared by NASA assistant administrator for programming DeMarquis Wyatt, April 13, 1966. Yet the controled reduction in personnel that NASA officials hoped to effect never really occurred. The dismissals and hiring freezes that began in fiscal 1968 signaled a reduction in manpower that continued well into the 1970s. The initial reductions did not

employees.

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merely have a ripple effect on the NASA work force; they also set the terms on which future programs, if approved, would have to be carried out.

TABLE 5

REDUCTIONS IN PERMANENT CIVIL SERVICE EMPLOYEES,

JULY 31, 1967-JUNE 30, 1970

These figures conceal the variations between centers, where there was no single pattern of accessions and separations. Two NASA installations, the Ames and Marshall Centers, show how differently research organizations could react to budget and personnel cuts, and how skills lost in one area might or might not be replaced in another.

The Marshall Center was particularly vulnerable to cutbacks, because its principal mission was the development of large launch vehicles. As the Saturn 1B and Saturn 5 went into production, headquarters officials came to believe that there was a manpower surplus at Huntsville that might be tapped by the rest of NASA. In effect, the center had three related problems: it was committed to a program that was tapering off; a high proportion of its facilities served specific programs rather than institutional needs; and it was perceived to have an excess of manpower in relation to future assignments.

When a major reduction in force began in the spring of 1968, the center was ill equipped to handle it. The turnover of R&D personnel alone was three times higher than it had been a year earlier, with losses especially heavy among the younger S&Es who could take jobs at the Redstone Arsenal nearby. According to center director von Braun, the worst effect of the RIF was that it disrupted work teams that had taken years to develop, with managers and supervisors relegated to the ranks of those they had supervised. With the departure of younger staff, and a concomitant rise in the average age of S&Es at Marshall, it became much less likely that the advanced research being done at the universities would be reflected in NASA laboratories.

At the Ames Research Center, Moffett Field, California, the transition was less dramatic, if almost as painful. Established in 1939 by the National Advisory Committee for Aeronautics, Ames had been primarily an aeronautical laboratory until the late 1950s. When NASA was created, the center took on

important new assignments in life sciences and space science, including the Pioneer series of interplanetary probes.[15] In common with other centers, Ames was caught in the backwash of Apollo-related cuts – or rather, cuts at the expense of other programs in order to keep Apollo going. In mid-1967, there were 2176 government employees at Ames; three years later, that number had fallen to just under 2000. Ames had to find new programs or sponsors to survive.

What permitted Ames to survive was the decision by center executives to concentrate on those areas where it was both strong and likely to attract funding from other agencies: computational fluid mechanics, flight simulation, life sciences, vertical takeoff and landing machines (V/TOL). These were the areas that could make the best use of existing Ames test facilities and draw support from the Army, the Federal Aviation Administration and the Defense Advanced Research Projects Agency (DARPA). Thus Ames used the Army to get funds for V/TOL research and DARPA to procure a supercomputer operated jointly by NASA and the Department of Defense. As DOD funds became available in the early 1970s, Ames management developed its rotary-wing research capabilities, to such effect that in 1975 Ames became the lead NASA center for work in short-haul aviation. There was, then, at least as much "push" from Ames as there was "pull" from NASA headquarters to chart its own course – one that very likely saved Ames from the fate of the Electronics Research Center.

The data on the separation of government employees is more complete than that on the termination of contractor employees. For one thing, much of the

15. Material on the Ames Center is adopted from Hans Mark and Arnold Levine, The Management of Research Institutions--A Look at Government Laboratories (Washington, DC: NASA Scientific & Technical Information Branch, 1984), pp. 79-82.

available data for the latter group refer only to prime contractors; and for another, while the ripple effects of cutbacks in aerospace employment were much more pervasive, they were for that reason less easy to pinpoint. Despite widespread belief to the contrary, overall S&E unemployment rates remained low even during the waves of layoffs in the late 1960s. According to a National Science Foundation survey, the rate of unemployment in the first half of 1971 was 3.0 percent for engineers and 2.6 percent for scientists.[16] Yet these figures rather conceal the disparities in unemployment rates among different S&E categories.

Thus NSF found that unemployment was highest (6.3 percent) among engineers previously in space activities; that of unemployed natural scientists, over half were chemists and physicists (3.0 percent and 3.9 percent respectively); that S&Es with doctorates had much lower unemployment rates than those with less education; and that workers under 25 had the highest unemployment rate (5.5 percent) in both engineering and the sciences. Rates dropped sharply in older age groups although, beyond 35, scientists' rates were persistently lower than engineers'.

Indeed, engineers were much more likely that scientists to face extended unemployment as they grew older. It was not that unemployed workers were older per se than those who continued to work. Rather, the Labor Department found in an unpublished study, older engineers had an above-average unemployment rate "because, once out of work, they [found] their age – and doubtless, the related problems of skill obsolescence and the higher salary of experienced workers – a handicap in seeking a new job."[17]

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16. These and subsequent figures are taken from the 1972 Manpower Report of the President (Washington, DC: U.S. Government Printing Office, March 1972), pp. 120-122.
17. Ibid., p. 122.

Paradoxically, unemployment in the space program may have acted as a "resource reservoir" for other government programs. On the one hand, the impact of layoffs in NASA program had severe, though temporary, impacts on localities such as Southern California and the Boston area, and on many smaller firms. Yet NASA cutbacks after 1966 created a reserve army of highly-trained professionals that was rather quickly absorbed by defense-related industries. According to a study by Mary Holman, in one two-year period about 49 percent of those separating from 136 NASA contractor plants transferred to other plants, mainly in the aircraft industry (Table 6).

TABLE 6

SHIFT IN EMPLOYMENT AT THE PLANTS OF NASA CONTRACTORS,

JUNE 1966-JUNE 1968

Source: Mary A. Holman, The Political Economy of the Space Program (Palo Alto: Pacific Books, 1974), p. 250. Table based on data supplied by Joint NASA/DOD Economic Information System and Bureau of Labor Statistics.

If anything, these figures understate the long-term effects of the space program on U.S. manufacturing, particularly the computer and semiconductor industries. Apollo affected these industries in several ways: by serving as a direct source of manpower to particular industries, encouraging the creation of new firms to meet its demands, and providing advanced training that could be transferred to other enterprises. In their book on The Economic Impact of Large Public Programs, Ginzberg and Kuhn have shown that Apollo was a major source of technical expertise for American industry. Thus IBM employees who managed NASA's real-time computer complex went on to develop major systems for the Federal Aviation Administration; Control Data employees who acquired real-time simulation experience on NASA projects did comparable work for Volkswagen and Grumman; while Univac engineers, several thousand of whom worked on NASA systems, went on to work for a variety of corporate clients.[18]

There remained, nevertheless, a core of professionals who had difficulty in finding work after they were let go. (In one way, scientists were at a disadvantage compared to engineers. While engineering and administration had much in common, scientists in the space program who dropped out of research got out of touch with their disciplines in a remarkably short time — a point that NASA recognized when it elected to draw the majority of principal investigators from outside the organization). There were a variety of state and Federal programs designed to assist them: retraining, seminars and a national job registry for engineers. One of the most ambitious of these programs, the Aerospace Employment Project, was noteworthy because it demonstrated very clearly that the skills of S&Es laid off from space-related projects could only with difficulty be transferred to other sectors.

18. Eli Ginzberg, James W. Kuhn, Jerome Schnee and Boris Yavitz, Economic Impact of Large Public Programs: The NASA Experience (Salt Lake City: Olympus, 197?), pp. 73, 75.

The U.S. Conference of Mayors and the National League of Cities sponsored the Aerospace Employment Project from 1971 to 1972.[19] The project was intended to find new careers in local government for S&Es laid off by cutbacks in space and defense programs. In Congress and some public interest groups, there had developed a belief that these technicians represented an untapped national resource and that the systems approach might pay off for the cities as it had for Apollo. The project's goal was to find out whether the professional skills of unemployed engineers could assist state and local governments to develop new techniques for solving problems in government operations.

The project leaders selected some 400 engineers and gave them a brief orientation in urban problems, before placing them with jurisdictions willing to hire persons with no experience in government. In a follow-up study of the project that MIT conducted, it transpired, first, that persons with general managerial experience moved more readily into government work than those with narrower experience in the hard engineering disciplines; second, that those engineers employed by project-oriented, rather than by manufacturing, organizations, were more likely to do well in public agencies organized by projects; third (and not surprisingly), that the better prepared the agencies were to use the skills of the engineers whom they hired, the more effective these engineers were likely to be.

The project demonstrated that, while the skills that engineers brought to their new jobs were transferable, the transfer went against the grain of the engineers' experience and training. Some of those placed left the moment they could return to aerospace work. Moreover, the project mostly placed engineers

19. Information on the Aerospace Employment Project is taken from an unpublished paper by Arnold Levine.

in existing vacancies rather than in specially created positions, so that candidates had to cope with the usual red tape - residency requirements, inflexible job descriptions, complicated hiring procedures. As the MIT report drily noted, "qualified applicants seeking jobs in local governments can become lost in . . . hiring mazes and they waste time dealing with the wrong person while the real process of hiring goes on in some other department . . . Internal political struggles, which only an insider can understand, may also negate placement efforts."

It would seem, then, that NASA was less successful in scaling down than it was in building up its work force. It was too decentralized for tight headquarters control of personnel management; and major shifts of work or manpower from one center to another could only occur gradually if they occurred at all. Additionally, projections of the national need for S&E manpower were imperfect at best and could only have been of limited use in building up Apollo employment. During the 1960s journalists, congressmen and some scientists accused NASA of siphoning off scientific manpower from areas with greater need, of possessing a disproportionate share of the nation's scientific manpower, and of attracting to itself a greater number of S&Es than its programs warranted.

Yet the main conclusion of the Gilliland Report and the annual Manpower Reports of the President - that the U.S. faced an impending shortage of engineering and scientific personnel - was almost certainly incorrect. By the early 1970s it was obvious that supply was outrunning demand in many fields - a result for which NASA could be held partially responsible. Again, while some laid-off S&Es had trouble finding work, the rate of unemployment in these fields remained quite low. On the evidence, many S&E professionals were able to make a successful transition: whether to defense contractors, to NASA

contractors doing defense-related work, to local government, or to centers within NASA that were diversifying within their primary missions.

NASA-University Grant and Contract Programs

But the long-term effects of Apollo extended beyond those persons working directly on the program. Through a network of contract and grants programs, NASA played an important role in encouraging university research in the physical sciencies – research that often was not tied to any specific mission. In so doing, NASA inevitably helped to set the direction for the kinds of research many universities carried on and the kinds of graduate programs they sponsored.

The growth of NASA's university programs mirrored Apollo's: moving from a modest level of effort at the beginning of 1961, growing ten-fold in the next five years and then dropping off to a plateau, one that the rate of inflation eroded steadily (Table 7).

TABLE 7

FUNDING OF NASA UNIVERSITY PROGRAMS, 1960-1977

Source: Homer E. Newell, Beyond the Atmosphere (Washington, DC: NASA Scientific & Technical Information Branch, 1980), p. 229.

The history of NASA funding conceals the changes in the philosophy behind the agency's university programs. As Table 7 shows, project-related work accounted for the preponderance of NASA grants to universities. But in some ways, Webb was seeking a less conventional approach. As he put it shortly after leaving NASA, one approach would have been "to state the projects in the form of immediate objectives and then request proposals from the academic community." This would have produced proposals but, at the same time, most research support "would have gravitated to those institutions that had already achieved the highest scientific reputations."[20]

Again, NASA could have continued the policies of other agencies to allocate funds to individuals chosen through nationwide competition, leaving to them the freedom to select the institution they wished to attend. NASA chose, instead, to provide predoctoral training grants to universities that were ready to build up their graduate schools, "allowing them to choose the graduate students and thus commit their brains and resources to their own selectees."[21]

NASA sponsored four major types of university program: predoctoral training, project-type research, facilities grants and the Sustaining University Program. According to one agency consultant, the predoctoral program had become a major source of support in the production of S&E doctorates.[22] By late 1965 over 3100 trainees were working toward doctorates at 142 universities in all 50 states. This was one of the most popular university programs: first, because of the relatively generous stipends and

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20. Webb, Space Age Management, p. 114.
21. Ibid., p. 116.
22. For a description of NASA university programs, see Donald J. Montgomery, Summary Report on the NASA University Program Review Conference, Kansas City, Missouri, March 1-3, 1965, SP-81 (Washington, DC: NASA Scientific & Technical Information Division, 1965).

three-year tenure; then, because of the summer institutes, which allowed young engineering or science teachers to do research at a NASA laboratory; and finally, because of the related undergraduate institutes that enabled students to work on research programs of their own choosing. Although the bulk of training program funds went for general instructional costs, NASA built flexibility in. Some funds were prorated into departments or allocated for new faculty positions or common-use equipment.

At the opposite end were those funds – and they were the bulk of the program – that went for space-related projects. Most of the funding sponsored research in specific disciplines such as astronomy, fluid dynamics, flight experiments on NASA spacecraft, as well as research on the social and economic impacts of the space program. In this last category, NASA contracted with several universities to study the technical spinoff from space technology. NASA officials believed that the universities were well placed to evaluate the commercial applications of space technology because, as one consultant put it, "the utilization (as contrasted with the mere acquisition) of technical information requires a close interaction between the supplier and the user. The universities are in good position to extend the work beyond the bare supplying of information, up to the further investigation that will lead to fruitful application."[23]

Some examples of NASA-sponsored research in technology utilization:

- The Midwest Research Institute applied NASA-developed technologies to units for electric-power conversion for railroad equipment, precision meter movements, electronic seals, telemetry, the setting-up of precision cutting tools, and electronic cell logging equipment.
- Wayne State University, Detroit, created a Center for

23. Ibid., p. 16.

the Application of Sciences and Technology to study and encourage the transfer of aerospace technology to nonspace industry.

- Indiana University, Bloomington, established an Aerospace Research Applications Center to alert industry to space-related technology that firms could use in their operations.

In 1961 NASA gained the legal authority to make facilities grants to universities. NASA made its first grant in the fall of 1962; and within a few months it was besieged by inquiries from universities around the country. The sums involved were not very great, certainly by comparison with what the Defense Department could offer. Yet the program had an importance out of proportion to the sums involved. In awarding such a grant, NASA expected the university to sign a memorandum of understanding in which i undertook to do two things. First, it agreed to study the technology transfer process itself, in an effort to apply a systems approach to the other social issues with which, as a university, it had to deal. And second, the university undertook to use its total competence in space-related research, with specialists from various disciplines working on the social and economic implications of the space program.

At this point, the facilities grant tended to merge with an even more ambitious enterprise, the Sustaining University Program (SUP). SUP was intended to support basic research of long-range significance. It was one thing, in Webb's view, to provide funds for a university's space science laboratory; another, and more valuable, to provide seed money for basic research loosely coupled to the NASA mission. Provided that the university signed a memorandum of understanding, NASA was willing to tailor its grants to almost any program that had a bearing on NASA activities.

Here are some examples:

- Texas A&M University used its SUP grant to undertake research in plasmas, polymer physics, cosmic radiation and aerospace structures, among others.

- The University of California in Los Angeles used some 50 grants as seed money in three scientific and technical areas, as well as in business administration. UCLA also used a portion of the monies to allow scientists to attend one-day, on-campus conferences, or for extended stays.

- The University of Pennsylvania established an Institute for Direct Energy Conversion, as one means of enabling engineering graduate students to do research in this area.

- At William & Mary, portions of the grant went to the biology department and (in much greater measure) to the physics department for work in upper-atmosphere research, plasma physics and high-energy physics. In this last area, the college had already joined with the University of Virginia and Virginia Polytechnic Institute to form a consortium to operate the proton synchrocyclotron at NASA's Langley Research Center nearby.

For all of NASA's success in persuading some 30 universities to sign memoranda of understanding, SUP largely failed of its purpose. The universities tended to regard the program as allowing them to do what they were doing - or would have done - in any event. NASA simply did not have the leverage or the money to redirect university research in the way that Webb would have liked. Further, all SUP funds to a university were obligated at the time of award. This meant that, once the award was made, NASA had little or no influence in determining how the money would be used.

But SUP failed for deeper reasons. For a university to have subordinated its goals to those of NASA would have gone against the grain of those faculty who, after all, would spend the money. Either the terms of the memorandum of understanding were beyond the university's capacity to accomplish; or the grants simply became another kind of "brick-and-mortar" funding, and the university behaved accordingly.

By mid-1966 NASA senior officials understood that SUP was failing, and that its shortcomings were inherent in the program and not due simply to lack of funds. By then, Webb had decided to wind up the program - not least because he came to believe that events had overtaken it. As Newell, who was closely involved with university programs, wrote:

> Added to Webb's disappointment with lack of performance on the memoranda of understanding was an emergent suspicion that the Gilliland Committee report might have grossly overestimated the need for new technical people in the nation's work force. Physicists and engineers, especially in the aerospace field, were beginning to have difficulty in landing jobs, and it was just possible that NASA's sizable graduate-training program might be exacerbating a serious national problem.[24]

The returns from investing in university research are at once among the easiest and the most difficult kinds of investment to quantify. Two years after NASA began to phase out the Sustaining University Program, an internal task force reviewed the impact of all of NASA's university programs. What its members found was that NASA grants had indeed made important contributions to the space program: university researchers had generated more than half the experiments flown on NASA spacecraft; some 250 universities had taken advantage of the opportunities to become involved in NASA aeronautics and space programs; and the Sustaining University Program had assisted more than 1000 students to earn doctorates in space-related areas.[25]

There was, however, a scarcely-concealed undertone of frustration in the

task force's report. Its members found that NASA had not fully reaped the benefits of its university programs, because there was no mechanism for translating research into applications. The close working relations between faculty and NASA professionals that Webb hoped for had not really developed, except in project-related research. NASA officials were tempted to either of two courses in their dealing with the universities. They could take a scrupulously hands-off approach, as they did with the SUP. In that case, as Newell observed, "one would have to rely on voluntary contributions to the activity by individual professors, which left the university administrators in a position of attempting to persuade their professors to join an undertaking the administrators themselves did not understand well enough to describe in very persuasive terms."[26] Or, NASA could insist that NASA-funded research be tied closely to agency programs. This was the real issue between NASA and the Jet Propulsion Laboratory, the facility operated under contract by CalTech. As the manager of NASA's deep-space programs, JPL was under pressure to become, in effect, a de facto NASA center while at the same time remaining an academic institution. This was beyond the capacity of CalTech or JPL officials to accomplish. NASA could tolerate certain JPL idiosyncracies, such as a penchant for doing everything in house, so long as JPL did not lose its ties with university research. What Webb expected of CalTech was that it should "do a superior job in dealing with the university scientists and thus in making the opportunities to do space science more readily available to academic institutions that might perhaps be possible in the government centers."[27]

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24. Newell, Beyond the Atmosphere, pp. 235-236.
25. Task Force to Assess NASA University Programs, A Study of NASA University Programs (Washington, DC: NASA Office of Technology Utilization, 1968), especially pp. 1-6.
26. Newell, Beyond the Atmosphere, p. 234.

The early failures of the Ranger and Surveyor programs led NASA to reappraise its relations with JPL. Although NASA officials considered annexing JPL, they ended by retaining it as an independent contractor. Yet JPL did become more like a NASA center. Under pressure, JPL hired a general manager and began to assign an increasing number of employees full-time to individual projects. In late 1964 NASA superseded its mutuality clause with CalTech with a proviso that NASA could assign tasks unilaterally, and it replaced the annual lump-sum fee with award fees based on performance.

Thus NASA's university programs had mixed results. They created a pool of scientists and engineers who could serve as principal investigators, project managers or support staff for government contractors. Yet the evidence reveals that while NASA could create a lively interest in certain disciplines, it had little control over the process once it began. In the mid-1960s, for instance, NASA was funding almost 40 percent of the astronomy doctorates awarded.[28] This occurred at exactly the point where the demand for astronomers peaked; and by the early 1970s the supply of astronomers exceeded the demand. The lesson, as Ginzberg noted, is that "government managers must be more sensitive to the longer term manpower consequences of their programs."[29] That, of course, presupposes that managers have the tools to foresee those consequences.

Some Longer-Term Effects of Apollo

By an interesting paradox, NASA's well-intentioned efforts to promote the transfer of Apollo-derived technology to commercial use were less successful

27. Newell, Beyond the Atmosphere, p. 267.
28. Ginzberg et. al., Economic Impact of Large Public Programs, p. 150.
29. Ibid., p. 151.

than the existence of Apollo itself in stimulating the U.S. electronics and computer industries. In the 1960s there were two opinions at NASA about the best way to effect technology transfers. One view held that it could best be promoted by creating an office with direct responsibility for technology utilization, and distinct from the line organization. This was created, but was never quite able to overcome the obstacles to such transfers that Federal agencies encounter at some point. The other view held that a program of Apollo's magnitude would inevitably spill over into the commercial sector, stimulating the growth of data-processing, integrated-circuit and materials technologies. And this is precisely what happened.

The short-lived Electronics Research Center revealed an even greater discrepancy between intentions and results. NASA gave several reasons for a separate center to do in-house research in electronics: Available equipment did not meet the needs of current and future space programs; because space electronics was a relatively new field, there was "no pipeline filled with proven components, techniques, and practices that [could] be used to build envisioned operational systems"; and there was little likelihood that such components would be developed independently.[30] NASA justified its selection of a site in the Boston area as a way of tapping the expertise of the local universities and R&D base.

But NASA stood virtually alone in seeing the need for such a facility. When PSAC's Panel on Government Laboratories visited the NASA centers in 1964, it praised the high morale of center employees, the existence of strong line management and the absence of the "aging" effects found in some older laboratories. But it took a dim view of the proposed electronics

30. These reasons are set forth in a letter from James Webb to Senate President Pro Tem Carl Hayden, January 31, 1964.

laboratory. This, the panel said, seemed unnecessary in view of existing capabilities within government and industry. Further, "that such a thing as 'space' electronics exists in the sense that space propulsion exists is highly debatable."[31] The PSAC report led NASA Deputy Administrator Robert Seamans to a stiff reply - one that apparently he never sent. NASA's position, Seamans argued, was that in space systems "there are problems unique to space exploration." The new center would do some of the work needed to fill the gap, but its mission was really more basic: "to stimulate and direct attention to electronic systems research and development that is needed to support NASA missions; and to evaluate work of this nature so that NASA can make more efficient use of it."

With hindsight, it can be said that PSAC had the better of the argument. (NASA closed the center in June 1970 and transferred the land and facilities to the Department of Transportation). In the Boston area alone, the work that NASA hoped to sponsor was being done by many firms; some, like Digital Equipment, Raytheon and Wang Laboratories, would become giant enterprises, while hundreds of small job shops would be absorbed by the larger, more successful defense and space contractors. More important, these firms were driven less by stated government policies, than by the procurement decisions that drove military and space programs throughout the 1960s.

It was the decisions, respectively, of NASA to use integrated circuits for the Apollo spacecraft guidance computer and of the Air Force, to use them for its Minuteman guidance package, that moved this technology into large-scale production.[32] In both cases, large government agencies were willing to

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31. President's Science Advisory Committee, Report of Panel on Government Laboratories (January 1965), p. 22.
32. Richard C. Levine, "The Semiconductor Industry," in Richard R. Nelson, ed., Government and Technical Progress: A Cross-Industry Analysis (New York: Pergamon Press, 1982), pp. 62-64.

pay high initial prices for technologies that were still unproven. At the same time, the large volume of orders that they conferred, the stringency of their specifications and their flexibility in using progress payments to ease cash-flow problems created new industries for investments that today seem almost derisory. From 1959 through 1964 the government allocated $32 million for integrated-circuit R&D, with the Air Force accounting for 70 percent of the total.[33]

Both the Defense Department and NASA showed a willingness to take risks that one seldom associates with Federal agencies. This willingness can be accounted for on the ground that both agencies had been assigned missions of the highest priority, and that no commercially-available technologies could meet specifications adequately. As Levin observes, "although no major technological breakthroughs were directly funded by the government, the Department of Defense stood ready at every critical junction to seize opportunities to develop the technical and production capability."[34]

Yet one has the clear impression in this area that the Defense Department was the leader and other agencies - including NASA - were followers. It was the success of the Air Force in stimulating the integrated-circuit industry that encouraged other agencies to sponsor related work. Thus in 1962 NASA partially funded the development of Texas Instruments' Series 51 computer; by 1964, the Air Force's share of total government R&D funds had dropped to less than 50 percent, although its own level of funding continued to rise.[35] NASA followed the Air Force's lead, because the latter agency had been involved in sponsoring the advanced technologies common to both agencies several years before NASA was created. Additionally, NASA and the Air Force had close

33. Ibid., p. 73.
34. Ibid., p. 68.
35. Ibid., p. 73.

working relations, owing to the need for common launch vehicles and facilities. They sponsored several working committees that monitored their common technical needs; and NASA relied heavily on Air Force detailees to manage many of its programs, write procurement specifications and negotiate contracts. It was surely no accident that Apollo program manager Major General Samuel Phillips (USAF) had been in charge of Minuteman before being detailed to NASA in 1964.

In sponsoring investments in electronics and computers, NASA and DOD officials were not consciously seeking an economic return on investment. Nor were they initially attempting to create a demand for specific categories of scientists and engineers. But the unintended — better yet, unplanned — results of these R&D programs were at least as important as those that were intended from the beginning. Once firms like Texas Instruments, Motorola or Westinghouse overcame the initial technical obstacles to mass producing integrated circuits, it became possible to train the professionals who could fine tune these products and take them to the point of commercial development.

The available evidence suggests that government funding for higher education became important at just the point where the most difficult technical obstacles were being overcome. And at that point government support came to matter a great deal. After increasing fourfold from 1950 to 1970, the number of doctoral degrees in physics declined 35 percent over the next decade.[36] Some of this funding, as noted, came from NASA, through its predoctoral training and Sustaining University programs. Yet, on the evidence, NASA played a supporting role to DOD in stimulating the electronics industry after about 1963-1964. In other words, it was as much a beneficiary of prior investments in semiconductors and computer equipment as it was a

36. Ibid., p. 84.

sponsor.

Conclusion: Implications of Apollo for the Training and Recruitment of Scientists & Engineers

The overriding conclusion of this paper is that NASA succeeded in finding or developing the scientific and engineering resources that it needed to accomplish the Apollo mission. During the early 1960s NASA managed to use its direct-hire authority to fill positions within the agency; it pressured its contractors to recruit the technical people from whose ranks would come the systems engineers, project managers and support personnel who proved indispensable to Apollo; and by a well-publicized grants program, it supported university research in all 50 states.

But NASA did not – and probably could not – have anticipated all of the long-term consequences of its recruitment policies. The available evidence confirms a recent study by the Office of Technology Assessment that "long-term projections of supply and demand for scientists and engineers in the economy as a whole are inherently unstable."[37] NASA officials accepted the conclusion of the Gilliland Report that the nation faced a shortage of scientists and engineers by 1970, only to discover four years later that they were contributing to a surplus of technical people that the economy could no longer absorb.

By then, NASA was faced with the need to start trimming its own work force. And here, the agency failed to make the orderly transition to the post-Apollo period that Webb and his associates anticipated. Between NASA's

37. U.S. Congress, Office of Technology Assessment, Demographic Trends and the Scientific and Engineering Work Force--A Technical Memorandum (Washington, DC: U.S. Government Printing Office, OTA-TM-SET-35, December 1985), p. 24.

peak in-house employment in July 1967 and the end of fiscal 1969, NASA abolished 2850 permanent positions. In the fiscal 1970 budget cycle alone, the agency sustained four separate reductions.[38]

The long-term effects of these separations affected NASA's ability to carry on much of its research, or to plan new flight projects. NASA was given very limited authority to replace personnel who had been separated; at Marshall, for instance, the replacement ration was 1 in 14. Many younger professionals left NASA, with a corresponding rise in the average age of those who remained. From the early 1970s to the 1980s, there was a steady increase in the average age of NASA scientists and engineers (Table 8).

38. Arnold S.Levine, Managing NASA in the Apollo Era (Washington, DC: NASA Scientific & Technical Information Branch, 1982), p. 136.

TABLE 8

AGE PROFILE OF NASA SCIENTISTS & ENGINEERS, 1975 AND 1982

Source: NASA. Personnel Programs Division, The Civil Service Work Force as of September 30, 1982, p. 15.

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It was not that the proportion of NASA scientists and engineers to total agency employment declined. Quite the contrary. As a single category, S&E's constituted just over half of NASA permanent employees, or two-thirds, if professional administrators were included. At the same time, the number of supervisors as a percentage of total NASA employees rose; in 1982, there was approximately 1 supervisor for every 6.7 employees agency-wide, while at headquarters the ratio was almost 1 to 5. But there were fewer scientists and engineers engaged in hands-on research. For one thing, there were no longer as many technicians available to support professional staff; for another, there was a sharp decrease in the number of bench-level scientists and engineers in the 30 to 39 age categories – precisely the people whose research ideas were most likely to lead to flight projects a decade or more down the road.[39]

Yet Apollo did create research capabilities that outlasted the program that created them. Because Apollo drew on all of NASA's resources, it compelled each center's managers to think of themselves as parts of a much larger organization. During the 1960s the "research" and the "development" centers tended to become more like each other; centers reporting to one program office began to work for others; and those centers, like the Ames and Langley Research Centers, with a mixture of smaller projects weathered the budget cuts at the end of the decade better than those, like Marshall, with enormous development projects that were winding down. The older NACA centers found themselves with a broad range of skills in aeronautics, life sciences and spacecraft design, many of them conferred by Apollo.

The impact of Apollo on S&Es employed by NASA contractors was even more

39. This discussion is based on Hans Mark and Arnold Levine, The Management of Research Institutions--A Look at Government Laboratories (Washington, DC: NASA Scientific & Technical Information Branch, 1984), pp. 140, 142.

complex. Some remained in space-related programs; other moved on to comparable work in the aircraft industry; while managers at higher levels moved back and forth between executive positions in industry, NASA and the Defense Department. On balance, NASA played a stabilizing role in the aerospace industry; as employment on Apollo declined, professionals became available for commercial or defense-related work elsewhere. As for those professionals who were laid off when NASA contracts were completed, the majority of those soon found comparable work, except among older engineers.

According to the OTA report cited earlier, "the essence of a labor market is that it adjusts."[40] But these adjustments are often anything but painless. When students respond to marketplace signals by making career changes, "this response is not a short-term remedy to a supply-demand gap because it takes 4 years to train a new engineer and 6 years (from the baccalaureate) to train a Ph.D scientists. In a fast-moving market, the needs of employers may change by the time entering students graduate." This describes rather well what happened to many of the graduate students that NASA sponsored in the 1960s. Although the unemployment rates for scientists and engineers in the early 1970s was relatively low, they were much higher than they had been only three to four years earlier - four-and-a-half times as high for engineers.[41]

What are the longer term implications of Apollo for the management of Federal research missions? Three observations are pertinent here. The first is, that Apollo embodied a certain approach to the management of large-scale endeavors that became very influential. As Webb put it, "it is the new and different way of doing things - of organizing the use of knowledge and

40. Office of Technology Assessment, Demographic Trends and the Scientific and Engineering Work Force, p. 25.
41. 1972 Manpower Report of the President, p. 121.

technology and human and material resources – rather than the new things themselves that is of most importance . . . This has been true even for endeavors like NASA and the Manhattan District, which might appear singularly dependent upon invention or 'new' knowledge and technology."[42] This implies that projects of such complexity require a new kind of manager: someone with a profound knowledge of the science and technology that the mission demands, and with the ability to motivate the government and contractor workers involved. Of necessity, such people are rare.

Problems arise when a style or discipline appropriate to one kind of program is transferred bodily to another. The same management approach – and even many of the same managers – that worked for Apollo was applied to the development of the Space Shuttle. To be sure, it could be argued that Apollo and the Shuttle were comparable, in that they were projects of inordinate complexity and technical difficulty. But for all its sophistication, Apollo was simple and its principles were well understood. No new technology was required in most instances. The Shuttle is far more complex and, until the Challenger tragedy, brought with it problems more like those of a commercial enterprise than of a government agency. The management and engineering skills that Apollo and the Shuttle demanded were not truly comparable.

This suggests a second conclusion. Precisely because endeavors on the order of Apollo, the Space Shuttle, the War on Cancer and the Strategic Defensive Initiative are not routine, it is seldom possible to specify in advance the manpower needs of each one. There is a "lumpiness," a discontinuity between the requirements of each program and the progress that can be made – even assuming that the program's budgetary needs are met. Again, Apollo was an exceptionally discrete, well-defined program with one

42. Webb, Space Age Management, p. 61.

main objective, albeit many secondary ones. This is less true of the Space Shuttle or SDI and holds least of all for a war on cancer. NASA knew when it had achieved the goals of Apollo; but there are no comparable criteria for determining when the goals of these other programs have been met, once and for all.

Finally, the tools available to Federal agencies for predicting their manpower needs are little more adequate now than they were in the early days of Apollo. Few of the mission-oriented agencies possess the kinds of analytical staff that would enable them to predict their needs accurately. And more important, meeting those needs depends on the interaction of more variables than any organization can expect to control. To be sure, there is an infrastructure of universities and contractors willing to participate in the right kind of endeavor. But mobilizing those resources is a political process, more than it is an administrative one. The Apollo experience, to be sure, can provide government executives with some general rules, such as decentralizing program management to the field, making the crucial decisions as rapidly as possible, and using all the authorities conferred by Congress and enabling legislation. But the great missions of the last 40 years have been, to some extent, sui generis. And further, the short-term success of NASA in building up to Apollo was followed by long-term problems with which the agency still grapples.

Table 1. — NASA scientists and engineers as a percentage of NASA employment, 1960–1968.
(30 June approximations)

Characteristic	1960	1961	1962	1963	1964	1965	1966	1967	1968
Contractor scientists and engineers									
Percentage of contractor employment	7 300	12 660	25 000	48 200	68 800	72 600	77 400	64 800	51 350
NASA scientists and engineers	20.0%	21.9%	21.6%	22.1%	19.8%	19.3%	21.5%	23.7%	24.3%
Percentage of NASA employment	3 500	5 800	8 200	11 000	12 400	13 500	14 300	14 500	13 715
Total scientists and engineers	34.3%	33.1%	34.6%	36.8%	38.2%	39.4%	39.7%	40.1%	39.2%
Percentage of total employment	10 800	18 400	33 200	59 200	81 200	86 100	91 700	79 300	65 065
	23.1%	24.5%	23.9%	23.8%	21.4%	20.9%	23.2%	25.7%	26.4%
Distribution of total scientists and engineers									
By employer (100%)									
Contractors	67.6%	68.5%	75.3%	81.4%	84.7%	84.3%	84.4%	81.7%	78.9%
NASA	32.4	31.5	24.7	18.6	15.3	15.7	15.6	18.3	21.1
By appropriation (100%)									
Administrative operations					15.5	16.6	16.5	18.5	21.7
Research and development					82.8	81.8	82.5	81.1	78.5
Construction of facilities					1.7	1.6	1.0	0.4	0.2
By program office (100%)									
University affairs					-	-	-	0.5	-
Technology utilization					0.1	0.3	0.3	0.2	-
Tracking and data acquisition					4.6	4.7	6.5	6.8	6.6
Advanced research and technology					14.3	12.5	10.2	11.5	13.3
Space sciences and applications					19.0	17.2	14.6	16.8	14.3
Manned space flight					62.0	65.3	68.4	64.2	65.4
By sector (100%)									
Government					15.3	15.7	15.6	18.3	21.1
Industry					81.9	81.2	81.8	78.3	77.1
University and nonprofit					2.8	3.1	2.6	3.4	1.8
Other characteristics (100%)									
Prime and subcontractors-R&D					71.8	70.7	67.2	64.8	68.2
Prime and subcontractors-COF					1.7	1.6	0.5	0.4	0.2
Service contractors-R&D					-	-	5.5	5.1	-
Service contractors-AO					0.2	0.9	0.9	0.2	0.2
Materials and supplies-R&D					8.1	7.9	7.3	5.6	8.5
University and nonprofit-R&D					2.8	3.1	2.6	3.4	1.8
NASA employees-AO					15.3	15.7	15.6	18.3	21.1

Source: *NASA Data Book*, table 1-27.

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Table 8-2. — Organizational sources of NASA in-house scientists and engineers.

Source	1961-62	1963-64	Difference
Total	*100.0%*	*100.0%*	-
Industry	32.4%	40.8%	+8.4
Federal Government	40.1%	28.9%	−11.2
College or university[1]	23.8%	23.3%	−0.5
Other[2]	3.7%	7.0%	+3.3

[1] Graduating students account for 20.8% in 1963-64 and 22.1% in 1961-62.
[2] Includes Nonprofit organizations, unemployed, and other.
Source: *Reply to Sen. Gaylord Nelson*, table III-A. NASA Staff Study of Recruitment Sources and Selected Characteristics of Scientists and Engineers Hired by NASA (1 Oct. 1962-30 Sept. 1964).

Table 3. — Total scientists and engineers on NASA work by program office, 30 June 1964.

Program Office	Total	Research and Development			Construction of Facilities		Administrative Operations	
		Prime and Sub	University and Nonprofit	Materials	Prime and Sub	Materials	Service Contractor	NASA Employees
Total	*71 200*	*58 300*	*2 300*	*6 600*	*1 400*	–	*200*	*12 400*
Office of Manned Space Flight	50 350	39 100	60	4 570	1 040	–	130	5 450
Office of Advanced Research and Technology	11 600	5 560	460	930	180	–	40	4 430
Office of Space Science and Applications	15 420	10 800	1 620	840	130	–	30	2 000
Office of Tracking and Data Acquisition	3 720	2 800	100	260	50	–	0	510
Office of Technology Utilization and Policy Planning	110	40	60	–	–	–	–	10

Source: NASA Management Information Systems Division (Office of Administration), *Scientists and Engineers and Total Employment on NASA Programs as of June 30, 1964*, table IV. 15 Dec. 1964.

Table 4. — NASA requirements for scientists and engineers compared with national requirements, 1960–1970.

Year (1 Jan.)	National Requirements[1]	NASA Requirements[2]	NASA Requirements as a Percent of National Requirements
1960	1 185 000	8 400	.7
1961	1 260 000	14 700	1.2
1962	1 340 000	22 000	1.6
1963	1 415 000	43 500	3.1
1964	1 495 000	68 600	4.6
1965	1 570 000	84 500	5.4
1966	1 645 000	87 900	5.3
1967	1 725 000	87 900	5.1
1968	1 800 000	87 900	4.8
1969	1 880 000	87 900	4.7
1970	1 955 000	87 900	4.4

[1] The data on national requirements are from preliminary estimates prepared by the Department of Labor, published in *The Manpower Report of the President* (Mar. 1963), pp. 100, 125, as follows: total scientists, 1960, 335 000; total engineers, 1960, 850 000; total scientists, 1970, 580 000; total engineers, 1970, 1 375 000. This table presents a linear interpolation between the key dates of 1960 and 1970. For 1960 through 1964, these data are estimates of persons employed in existing positions. For 1965 through 1970, the data are projections of *requirements*, not *supply*.

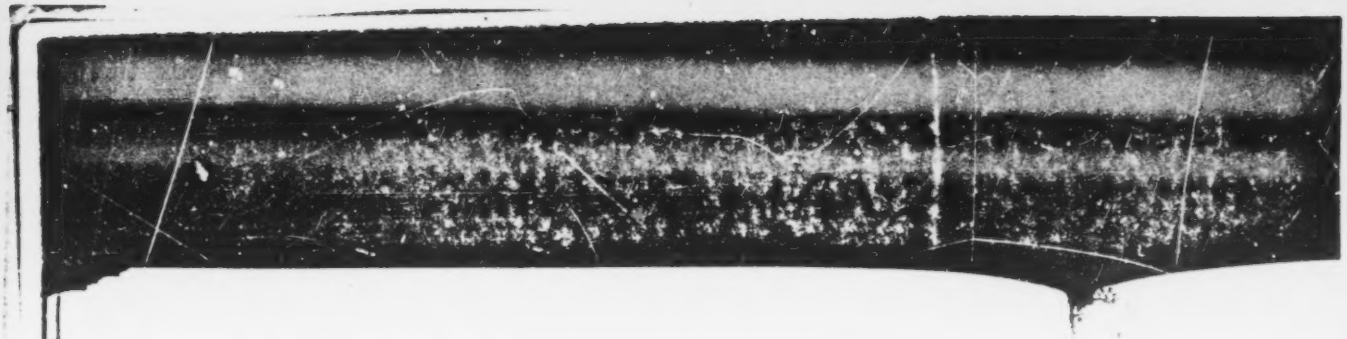
[2] The estimates of NASA requirements for 1967 through 1970 are projected at a constant level assuming a budget program of approximately $5.2 billion annually.

Source: NASA Management Information Systems Division (Office of Administration), *Scientists and Engineers and Total Employment on NASA Programs as of June 30, 1963*, table IV, 15 Dec. 1964.

Table 5 Reductions in permanent civil service employees, 31 July 1967–30 June 1970.

Installation	Peak Employment 7/31/67	Change in FY 1968	Actual 6/30/68	Change in FY 1969	Actual 6/30/69	Planned Change in FY 1970		Planned 6/30/70
						Increase	Decrease	
Headquarters (including NASA Pasadena Office)	2 332	−178	2 154	−61	2 093	+37		2 130
Kennedy	2 739	+178	2 917	−40	2 877	+4		2 881
Manned	4 862	−258	4 604	−220	4 384		−77	4 303
Marshall	7 272	−832	6 440	−291	6 149		−298	5 851
OMSF	14 873	−912	13 961	−551	13 410	+4	−375	13 035
Ames	2 176	−93	2 083	−91	1 992		−36	1 956
Electronics	738	+56	794	+6	802	+98		900
Flight	598	−32	566	−27	539		−5	534
Langley	4 251	−214	4 037	−125	3 912		−63	3 849
Lewis	4 703	−251	4 452	−184	4 268		−71	4 197
SNPO[1]	115	−7	108	−4	104		−5	99
OART	12 581	−541	12 040	−423	11 617	+98	−180	11 535
Goddard:								
Base	3 828	−133	3 695	−166	3 529		−82	3 447
Contractor conversion	-	+127	127	+473	600	+365		965
Wallops	512	−18	494	−10	484	+4		488
OSSA	4 340	−24	4 316	+297	4 613	+369	−82	4 900
Undistributed reduction	-	-	-	-	-	-	−100	−100
NASA	34 126	−1 655	32 471	−738	31 733	+508	−741	31 500
Recapitulation:								
Base	34 126	−1 782	32 344	−1 211	31 133	+143	−741	30 535
Contractor conversion[2]	-	+127	127	+473	600	+365	-	965

[1] Space Nuclear Propulsion Office.
[2] Contractor conversions are treated as decreases in NASA employment.
Source: Thomas O. Paine to Robert P. Mayo, Director, U.S. Bureau of the Budget, 18 Aug. 1969, table I.



June 1966 and June 1968 about 49 percent of those separating from the space program transferred to other plants. It is most probable that the majority transferred to plants in the aircraft industry, because total employment in the guided missiles component of the aerospace industry witnessed a decline of 4 percent during the two-year period.

TABLE 6 SHIFT IN EMPLOYMENT AT THE PLANTS OF NASA CONTRACTORS, JUNE 1966–JUNE 1968

INDUSTRY SECTOR	CHANGE IN NASA EMPLOYMENT	ABSORPTION CAPACITY AT NASA PLANTS	CHANGE IN INDUSTRY EMPLOYMENT
Guided missiles and space vehicles[a]	−31 percent	DOD absorbed 79 percent; other government and commercial absorbed 15 percent; 6 percent left NASA plants.	−4 percent
Aircraft and parts[b]	−39 percent	Commercial and other government employment also down; DOD employment absorbed 40 percent of NASA, other government, and commercial decrease; 60 percent left NASA plants.	+15 percent
Electrical equipment[c]	−54 percent	DOD absorbed all of NASA decrease; other government and commercial up substantially; 12 percent rise in total employment at NASA plants.	+3 percent
Business and engineering services[d]	−22 percent	DOD employment absorbed 30 percent; other government and commercial absorbed 48 percent; 22 percent left NASA plants.	+9 percent[e]
Total employment at NASA plants	−43 percent	DOD employment absorbed 42 percent of decrease; other government and commercial absorbed 9 percent; 49 percent left NASA plants.	Total employment up 3 percent

[a] SIC 1925
[b] SIC 372
[c] SIC 36
[d] SIC 891 and 737
[e] SIC Only 891

Sources: Joint NASA/DOD Economic Information System, and U.S. Department of Commerce, Bureau of Labor Statistics.

GEOGRAPHIC EMPLOYMENT INSTABILITY

In addition to the fact that federal procurement cycles frequently do not correspond in amplitude or in timing to economy-wide business cycles, procurement cycles can induce severe fluctuations in the eco-

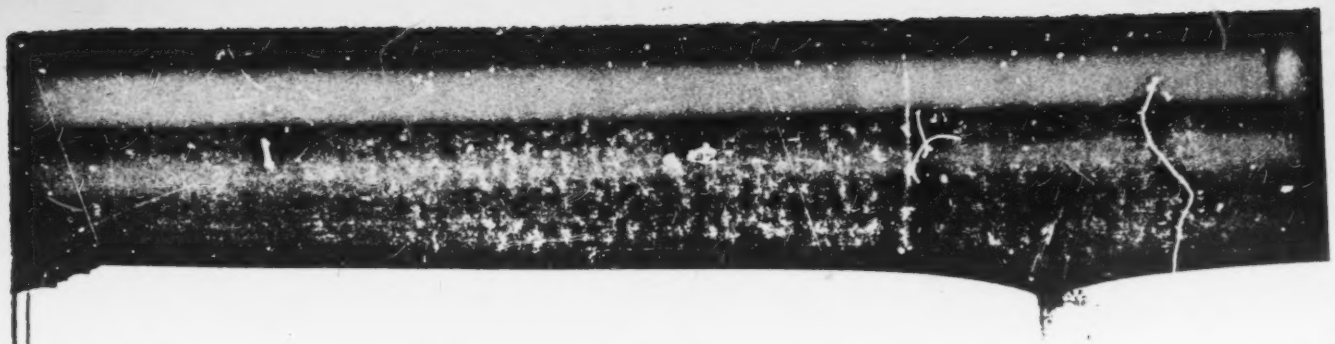


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TABLE 7
FUNDING OF NASA UNIVERSITY PROGRAMS, 1960-1977

Excludes obligations to or through federally funded research and development centers (JPL, Lincoln Lab., SREL).
Change in status from "university" to "nonprofit" for three organizations accounts for $10.1 million of the difference between FY 1973 and FY 1974 (Draper Lab., ERIM, Dudley Observatory).
Office of University Affairs includes 1962-1971 sustaining university program.
Omitted obligations: transition period (July-Sept. 1976), $27.7 million; FY 1959, $3.6 million.

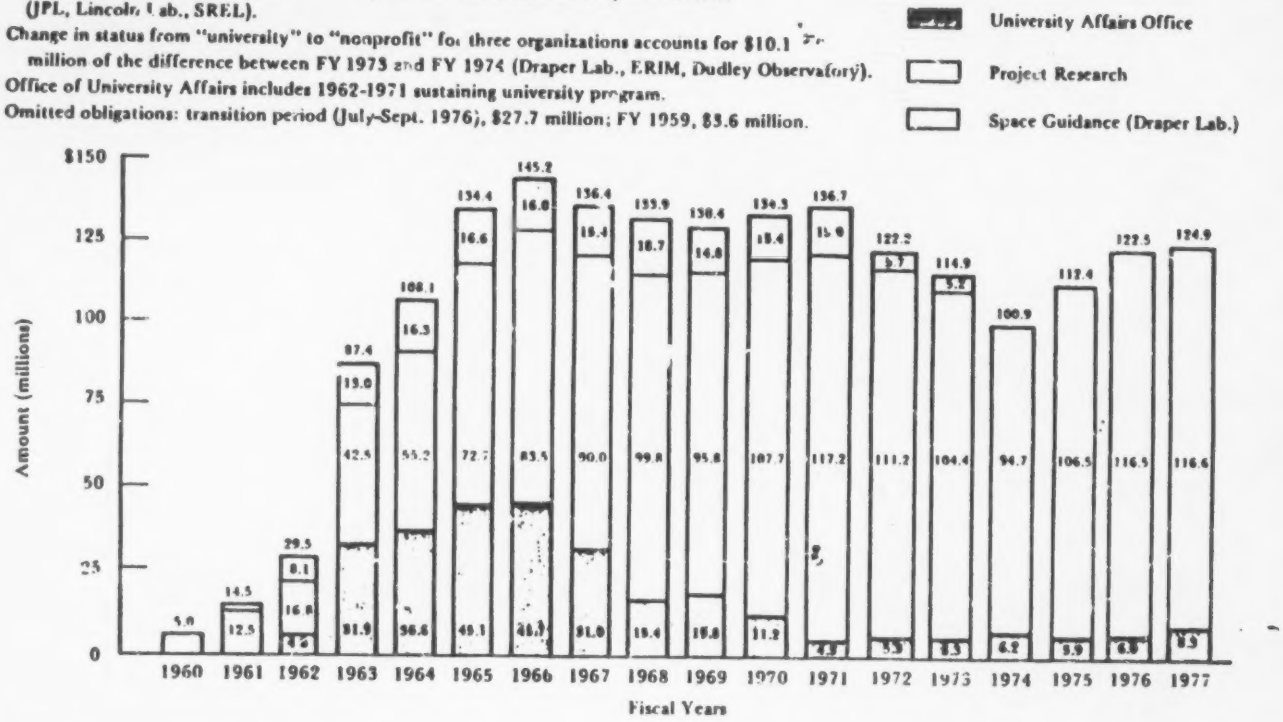
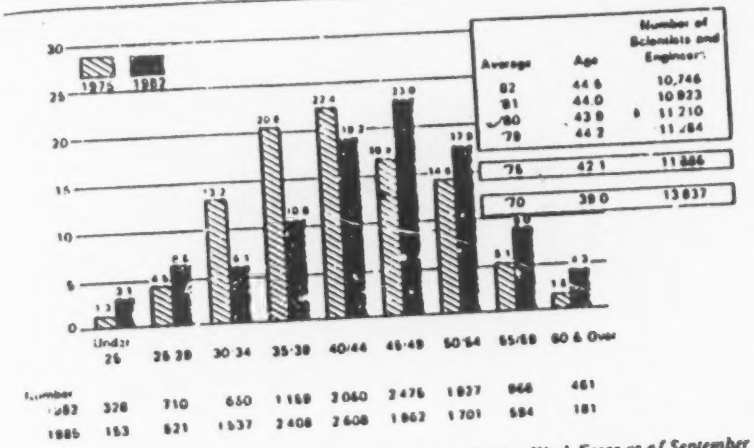


Figure 45. Funding NASA's university program. The sustaining university program had a special importance; nevertheless, the major part of the funding came from the technical program offices. NASA University Affairs Office, chart P77-158(1), rev. 1, 1978.

TABLE 8



Source: NASA, Personnel Programs Division, *The Civil Service Work Force as of September 30, 1982*, p. 15.

FIGURE 43.—*This figure shows the age profile of NASA civil service scientists and engineers in 1975 and in 1982.*

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